

Policy Statement on Efficient Water Management for Conservation by Agricultural Water Suppliers

Efficient Water Management Practices for Agricultural Water Suppliers

On-Farm Practices

March 1994

State Water Conservation Coalition
a joint project of
Committee for Water Policy Consensus
Southern California Water Committee

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It was not possible to eliminate duplicates from the many mailing lists used to broadly distribute this publication. If you received more than one copy of this document, please pass along any extras to those who might find its contents of interest or value.

Introduction and Purposes

The two papers in this publication are the product of more than four years of concerted, good-faith, consensus-driven efforts by the State Water Conservation Coalition's geographically-broad Agricultural Conservation Task Force. (See Exhibit 2 for a list of task force members and "interested parties" to the task force's work.)

In March 1989, the northern California-based Committee for Water Policy Consensus and the Southern California Water Committee jointly initiated an ad hoc cooperative project focused on conservation and efficient use of water: the State Water Conservation Coalition (SWCC or Coalition). (See Exhibit 1 for a "List of Representatives" to the Coalition.) The Coalition set about to identify reasonable and practical programs which can be implemented and appropriate amounts of water that can be conserved and used more efficiently statewide. In July 1989, the SWCC established four technical task forces (listed below) to help it develop recommendations to the California State Water Resources Control Board (SWRCB):

- Agricultural Conservation
- Reclamation/Reuse
- Urban Conservation
- Voluntary Water Transfers & Exchanges

The SWRCB in 1987 launched a multi-year, multi-phase hearing process to establish water quality standards for the San Francisco Bay-Delta Estuary and to develop implementation measures to achieve those standards. The information compiled and the conclusions accepted by the Coalition were for the express purpose of offering specific recommendations to the SWRCB in connection with its Bay-Delta Hearings, recognizing that the Coalition's work might be of value in other forums as well.

It is clear that any future water allocation plan in California will place an increasing emphasis on more efficient use of our water supplies. The State Water Conservation Coalition -- a historic partnership -- for the first time in California brought together north and south, joined by agriculture, urban water agencies, public and business interests, to work in a focused, cooperative effort to evaluate and quantify, where possible, the potential for additional water savings statewide, urban and agricultural.

The Policy Statement prepared by the Coalition's Agricultural Conservation Task Force -- and endorsed by the SWCC -- is directed at the agricultural water supplier level and includes a descriptive list of 19 Efficient Water Management Practices (EWMPs) that it is recommended be implemented (as appropriate and economically feasible) by suppliers.

The final draft Policy Statement was widely circulated in the Spring of 1993 for review and comment: in addition to all those on the ACTF's roster (Exhibit 2), the Policy Statement was sent to the Secretary of the California Resources Agency and the

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Director of the California Department of Water Resources (DWR) for review and feedback and to be of use to the Governor's Water Policy Task Force; the paper also was sent to all agricultural water supplier members of the Association of California Water Agencies for their review.

The key policy element in this Policy Statement is a commitment by agricultural water suppliers to a detailed water conservation planning and management process.

This Policy Statement, in combination with its list of Efficient Water Management Practices, has served as a useful starting point for development of an agricultural conservation implementation mechanism. The Agricultural Conservation Task Force's draft policy statement and list of EWMPs was provided to the AB 3616 Advisory Committee (created as a result of the enactment of the "Agricultural Water Suppliers' Efficient Water Management Practices Act") as its starting point when it was organized in February 1991 by DWR.

Efforts to negotiate a broadly-supported agricultural conservation Memorandum of Understanding comparable to the path-breaking urban conservation MOU-- negotiated under SWCC and DWR auspices -- as of this date is continuing to go forward under the sponsorship of the AB 3616 Advisory Committee. Many of the representatives who served on the Coalition's Agricultural Conservation Task Force (ACTF) also serve on the AB 3616 Advisory Committee.

The key policy element (commitment by agricultural water suppliers to a detailed water conservation planning and management process) and the implementation of EWMPs by suppliers that were pioneered by the Coalition's ACTF have been broadly accepted by other entities and are cornerstones of the agricultural conservation MOU currently being negotiated.

Additionally, the U.S. Bureau of Reclamation used the Coalition's ACTF Policy Statement paper and list of EWMPs when the Bureau drafted criteria for water conservation plans to be developed and implemented by all contractors to federal Central Valley Project (CVP) water. (Having approved plans in place is a new requirement under the CVP Improvement Act, signed into law in October 1992.)

In February 1992, the Coalition directed the ACTF to develop an on-farm practices paper so that the full breadth of conservation opportunities within the agricultural sector -- including the supplier level and the on-farm level -- could be considered. The draft "On-Farm Practices" paper was circulated to a wide variety of organizations for comment: in addition to all those listed on Exhibit 2, the paper also was sent to the Agricultural Caucus, California Cattlemen's Association, Committee for Water Policy Consensus (CWPC), Southern California Water Committee (SCWC), and

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Western Growers Association. The final "On-Farm Practices" paper has been approved on behalf of the SWCC by the Coalition's two major sponsors: the CWPC and the SCWC.

The "On-Farm Practices" paper has two primary purposes:

- To enhance the public's understanding of agricultural water use and the many factors involved in irrigation management decisions.
- To identify and promote the aggressive implementation of on-farm practices that will economically improve water use efficiency.

For the farmer, the list of specific on-farm practices may serve as a convenient checklist and to encourage investigation of possible improvements to current practices.

The Coalition efforts were concentrated on identifying the range of policies, programs, and practices that will achieve conservation and more efficient use of California's water resources. **It is not the purpose of the Coalition nor the two papers in this document to recommend what should be done with any water conserved through implementation of efficient on-farm practices or implementation of EWMPs by agricultural water suppliers.**

It is the Coalition's hope that the papers in this document, which has been broadly distributed, will serve as a useful reference document for growers, will stimulate even more aggressive efficient water management programs and practices by agricultural water suppliers and by farmers, and serve as a useful educational and informational source for public interest and environmental organizations.

State Water Conservation Coalition

List of Representatives

(as of March 1992)

Committee for Water Policy Consensus

Honorable Sunne Wright McPeak, SWCC Co-Chair, Supervisor, Contra Costa County
 Honorable Al Aramburu, Supervisor, Marin County
 Roberta Borgonovo, League of Women Voters of the Bay Area
 Robert Brownstein, Office of Supervisor Wilson, Santa Clara County (March 1989 - December 1990); Office of the Mayor, City of San Jose
 Honorable Osby Davis, Supervisor, Solano County
 John DeVito, Contra Costa Water District (March 1989 - February 1990)
 Tom Fox, East Bay Municipal Utility District
 Tom Graff, Environmental Defense Fund
 Lori Griggs, CWPC Executive Director
 Andrew Johnson, Contra Costa Water District (March 1989 - February 1992)
 Ronald L. Johnson, Marin Municipal Water District
 Joe Judge, Santa Clara Valley Water District
 Clifford Koster, San Joaquin County Farm Bureau
 Norman Lougee, San Francisco Water Department
 Ed Seegmiller, Contra Costa Water District (March 1989 - February 1990)
 Honorable Judy Stabile, Councilmember, City of San Jose
 Honorable Susanne Wilson, Supervisor, Santa Clara County (March 1989 - December 1990)

Southern California Water Committee, Inc.

Honorable Ben Austin, SWCC Co-Chair, Supervisor, Kern County
 Honorable John Flynn, SWCC Co-Chair, Supervisor, Ventura County (March 1989 - February 1992)
 Joan Anderson, SCWC Executive Director
 Lynn Anderson, Ventura County (March 1989 - November 1990)
 Earl Burke, Anheuser-Busch
 Honorable Gil De La Rosa, Mayor Pro Tem, City of Pico Rivera (August 1989 - April 1990)
 Honorable Susan Golding, Supervisor, San Diego County (March 1989 - April 1991)
 Bill Hill, Office of Senator Ruben Ayala; Board of Directors, Metropolitan Water District of Southern California
 Rex Laird, Ventura County Farm Bureau

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STATE WATER CONSERVATION COALITION, LIST OF REPRESENTATIVES

Armando Lopez, Ag Land Services (July 1990 - November 1990)
Dan Masnada, Newhall Land & Farming Company
Jack Michael, County of Los Angeles
John Morris, Irvine Ranch Water District
Theo Nowak, former General Manager, Chino Basin Municipal Water District
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Lester A. Snow, San Diego County Water Authority
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Peer Swan, Irvine Ranch Water District
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Other Representatives

Gloria Anderson, League of Women Voters of California
Carl Boronkay, Metropolitan Water District of Southern California; California
Urban Water Agencies
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Polly Smith, League of Women Voters of California (alternate)
Richard Spees, California Manufacturers Association
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State Water Conservation Coalition Agricultural Conservation Task Force Roster

(as of April 1993)

Agricultural Conservation Task Force Members:

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Gloria Anderson, League of Women Voters of California
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Robert Hagan, Professor Emeritus, University of California, Davis
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Ray Hoagland, California Department of Water Resources
Dan Johnson, U.S. Soil Conservation Service
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Rex Laird, Ventura County Farm Bureau
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Ralph Menvielle, Imperial Irrigation District
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ACTF Interested Parties:

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Staff Support:

Lori Griggs, Executive Director, Committee for Water Policy Consensus

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First and foremost, we want to acknowledge with profound appreciation the time, effort, and commitment by the many **Agricultural Conservation Task Force members**, joined at times by a number of "**interested parties**," who spent four years volunteering their time to craft the consensus-driven Policy Statement (including its list of nineteen Efficient Water Management Practices) and the nuts-and-bolts On-Farm Practices paper (which also has its philosophical side in the "Guiding Principles" section).

Given all the external events at work during this period of time (1989 - 1993) -- including Congressional efforts to reform the federal Central Valley Project, a multi-year drought in California leading to reduced water allocations and precipitously declining fish and wildlife species, and intense disagreements about the State Water Resources Control Board's efforts to set water quality standards to protect the San Francisco Bay-Delta Estuary -- those involved in developing these two papers deserve a great deal of credit for staying with the process.

These two papers represent a significant achievement on the part of all those who helped to draft them. Agricultural representatives also deserve much credit for their effort to be proactive on conservation and improved water management issues.

While the development of these papers was a group effort, several individuals deserve special thanks for extra efforts, including:

- Supervisor **John Flynn** (Ventura County) and Supervisor **Sunne Wright McPeak** (Contra Costa County) for their vision and leadership in bringing their two respective organizations (the Southern California Water Committee and the Committee for Water Policy Consensus) and others together in a cooperative project, the State Water Conservation Coalition, which accomplished much of value in the areas of conservation and efficient use of water.
- **William I. DuBois** (California Farm Bureau Federation) for his tenacious guidance of the Agricultural Conservation Task Force, serving as its convener from start to successful finish.
- Selected ACTF members for special technical assistance with the On-Farm Practices paper: **Baryohay Davidoff; Grant Davids; Lloyd Fryer; Robert Hagan; Dan Johnson; James Moore, Jr.; Bill Richardson; Tracy Slavin; and Byron Steinert**; and to **Stuart Pyle** for drafting the "Guiding Principles" section, a strong set of principles that amounts to a farmer's water use ethic.
- **Sami Yassa and Hal Candee** (Natural Resources Defense Council) for their suggestions to improve the Policy Statement by adding more specificity and detail, particularly to the conservation plan called for in the Policy Statement.

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Their efforts, joined by other environmental and public interest group advocates, were largely successful as the agricultural representatives made a commendable, good-faith effort to address and incorporate NRDC's recommendations.

The CWPC's Executive Director, **Lori Griggs**, for her patience, perseverance, and professionalism in providing staff support to the ACTF on behalf of the Coalition for the four years of task force work and the time spent beyond that in bringing these papers to publication, distribution, and public awareness.

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The **Kern County Water Agency** for typesetting, designing, and providing camera-ready copy of this document. In particular, we appreciate **Lloyd Fryer** for making this generous offer of support possible and for making happen the production of the camera-ready copy. We also thank KCWA's graphic designer, **Brenda Fowler**, for her excellent work.

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Policy Statement on Efficient Water Management for Conservation by Agricultural Water Suppliers

In recognition that California's developed water supplies are a limited resource with numerous beneficial uses, agricultural water suppliers support effective water management programs as part of an expanding conservation ethic for all Californians. The State Water Conservation Coalition (SWCC) recommends that agricultural water suppliers shall continue to plan, evaluate and implement measures that will achieve greater efficiencies and greater conservation. Reliability of agricultural water supplies is fundamental to achieving conservation benefits.

*Included in intended and essential uses are: satisfying crop evapotranspiration, providing a leaching fraction, water for necessary cultural practices, and enhancing groundwater storage through deliberate, non-incident recharge.

"Water conservation" as related to agriculture means the reduction of the amount of water consumed or lost 1) through seepage or flows to saline sinks; 2) through other forms of water degradation; 3) through incidental losses to unintended or non-essential uses¹, or 4) through evaporation. Savings can be achieved by 1) improving the technology or the methods for diverting, transporting, delivering, reusing, salvaging, or recycling water; 2) adopting policies that create financial incentives to save water and discourage inefficient practices; or 3) implementing other conservation methods. "Efficient Water Management" (EWM) means reasonable and economically-justifiable practices within these general categories. The objective of Efficient Water Management Practices (EWMPs) is for suppliers to better serve farmers, including responding to irrigators' requests for delivery of water, especially on short notice, in order to facilitate the efficient use of water.

The goal of EWMPs is to achieve a net positive effect on water supply, water quality, and on the environment, both within and outside of the supplier's service area. The SWCC recognizes that additional facilities may be needed to enhance certain water conservation programs, provided there is a net positive effect for the environment from such facilities.

EWMPs are limited to actions that may be taken by suppliers who deliver water for agricultural purposes. These actions should promote improvements in on-farm practices. However, it is not the purpose of this policy statement to address on-farm irrigation. Nevertheless, the SWCC recognizes that considerable water savings potential exists in some areas through improved on-farm practices.

The SWCC recommends that agricultural water suppliers commit to a water conservation planning process that assesses, evaluates and implements additional EWMPs where appropriate. As part of this process, suppliers must commit to produce and implement a system-wide conservation plan. The purpose of an effective conservation plan is for

each supplier to establish a comprehensive and continuous commitment to identify, evaluate, and implement EWMPs. The Plan should contain the following elements:

- A. a system-wide water conservation goal, or a target irrigation efficiency, based upon an assessment of water conservation potential. Clearly, water conservation potential varies considerably between districts and between different growers within a district, depending upon factors such as specific soil conditions, microclimates, and previous measures to conserve water.
- B. a water management improvement inventory, which should include a list of EWMPs which are determined as applicable for that supplier in achieving its water conservation target and the estimated economic costs of each such measure.
- C. an evaluation of the reasonableness and cost-effectiveness of each EWMP or combination of EWMPs.
- D. a schedule of implementation and a budget for a specified time period.
- E. an assessment of the performance of previously implemented EWMPs, including the amount of water saved. Supplier monitoring and evaluation is needed in all areas to determine the results of EWMPs.
- F. a process and incentives for achieving compliance with goals or targets.

The SWCC also urges appropriate agencies at all levels to provide assistance and incentives to prepare plans as well as help implement EWMPs, including enforcement of existing requirements for districts to prepare water conservation plans.

Every effort must be made by the supplier to achieve the water conservation target. Because the application of EWMPs is based on local conditions and the overall conservation potential of each supplier, the water conservation potential will vary among suppliers. Also to be considered in conservation plans are programs that involve actions among suppliers or on a regional or inter-regional scale.

Water quality considerations often extend beyond the service area of a supplier. EWMPs strive to maximize the reasonable and beneficial use, including multiple use of water, before the water is irretrievably lost, and strive to avoid commingling water of un reusable quality with higher quality waters when the combined beneficial value of the water is thereby diminished. The salt load contained in the water also must be monitored and managed, particularly when the water is used and reused and then discharged to a receiving water body.

The SWCC has prepared the following list of practices intended to help agricultural water suppliers achieve efficient water delivery and facilitate efficient farm use. This recommended list of EWMPs is limited almost entirely to practices which promote the efficiency of agricultural water use. EWMPs are only one of several options, all of which have an unquantified potential for reducing water use, some of them controversial.

Efficient Water Management Practices for Agricultural Water Suppliers

The key policy recommendations included in the State Water Conservation Coalition's "Policy Statement on Efficient Water Management for Conservation by Agricultural Water Suppliers" focus on water conservation planning to increase water use efficiency. Such planning and implementation emphasizes Efficient Water Management Practices (EWMPs) that include but are not limited to activities and policies that: 1) evaluate the efficiency of the current storage, delivery and drainage disposition of water; 2) measure and account for water applied; 3) provide water to farmers on demand (also known as arranged-demand water delivery); 4) line canals to prevent seepage to unintended uses; 5) evaluate and recommend improvements to the uniformity with which water is applied; 6) assist farmers in calculating the optimum time and amount of water to apply; 7) provide farmers with financial or other incentives to improve the efficiency of water use; 8) implement water pricing policies that discourage wasteful use of water; 9) estimate district-wide water balance; 10) initiate and strengthen water conservation and management plans; and 11) adopt performance goals where appropriate. EWMPs are organized into three major categories: A. Irrigation Management Services; B. Physical and Structural Improvements; and C. Institutional Adjustments; these EWMPs are described below. Some EWMPs may not be appropriate or economically feasible for all suppliers.

While EWMPs are targeted at actions and policies to be carried out by agricultural water suppliers, it is important to acknowledge that agriculture also relies on investigations, research, and advice from consultants and other organizations. Any implementation mechanism must recognize the long-term water management and conservation effort which began in the late 1800s with the development of the land grant universities dedicated to agricultural research. Equally important developments include the federal-state-county-supported agricultural Cooperative Extension programs initiated in 1917, and the U.S. Soil Conservation Service and local Resource Conservation Districts which undertook programs beginning in the 1930s. A strong implementation mechanism for agriculture requires recognition of these existing programs and that suppliers include these programs, as appropriate, in their agricultural water conservation and efficient management efforts.

¹ **Evapotranspiration (ET):** the quantity of water transpired from plant tissues and evaporated from surrounding soil surface, expressed as a depth of water in inches or feet.

² **Leaching requirement:** the amount of water required to flush a sufficient quantity of accumulated salts from the root zone downward to maintain full crop productivity.

A. Irrigation Management Services

1. Use historic and current crop water use data (evapotranspiration¹ plus leaching requirement²).

To promote efficient water management, agricultural water suppliers should make available to farmers data helpful in adjusting irrigation schedules and improving irrigation water management.

To be more efficient in the management of water, agricultural water suppliers typically use two types of historic data in their planning process: 1) their own evapotranspiration (ET) records for various crops from past years; and 2) historical ET data for their region or area. Historical ET data has been published for a number of areas in California by the Department of Water Resources (DWR).

Historical ET data is primarily a planning tool. To more accurately estimate water needs in a region during the growing season, current ET data should be used. The ET of a reference crop is available from data supplied by a series of DWR-operated climate stations, located throughout California, called California Irrigation Management Information System (CIMIS), and from other services. These can be used with verified coefficients to estimate crop ET.

Values of ET are really estimates of actual water use by specific crops/fields. The next step in efficient water management depends upon farmers within the supplier's service area. Devices or methods which monitor the actual soil moisture in the crop root zone should be promoted by suppliers to assist farmers in accurately scheduling irrigations. Farmers should be encouraged to use devices such as tensiometers, moisture blocks, neutron probes, and soil probes in order to determine crop water needs. These devices or methods are very effective when used in conjunction with ET data to more precisely schedule irrigations.

2. Provide an irrigation specialist and/or consultant.

Agricultural water suppliers should consider obtaining the services of irrigation specialists or consultants experienced in on-farm water management. These specialists can monitor water management practices in the area and provide farmers information which may improve on-farm water management. Larger suppliers may employ an irrigation specialist, while smaller suppliers may desire to share the services of an irrigation specialist or consultant. (Suppliers may provide farmers information on: weather, crop ET, soil-moisture holding capacity, crop characteristics, irrigation scheduling, and water-use planning. These irrigation specialists also can help farmers solve individual water management problems.)

3. Monitor salinity to maintain favorable salt balances³ in the crop root zone.

Salinity management requires careful monitoring of all the forces acting upon the water, soil, and crop. Each requires monitoring to determine leaching requirements, based upon the salinity of applied water, amount of drainage effluent, crop tolerance levels, economics, etc. Leaching to correct salt accumulation requires additional water.

³ **Salt balance:** the condition when the amount of salts added to a soil profile through irrigation and the amount removed by leaching are equal (i.e., no net gain nor loss of salt in the crop root zone). This balance will be established if adequate leaching occurs. The average root zone salinity will depend upon the amount of leaching and the quality of the applied water.

EFFICIENT WATER MANAGEMENT PRACTICES FOR AGRICULTURAL WATER SUPPLIERS

***Distribution uniformity:** the ratio of the minimum depth of water infiltrating within a field to the average depth of water infiltrating the whole field.

***Mobile Labs program:**
Developed by DWR's Office of Water Conservation and funded by the State Water Resources Control Board, the Interagency Mobile Agricultural Water Conservation Laboratory (Mobile Labs) is an educational and demonstration program involving irrigation systems operation and management. The program's purpose is to inform farmers of irrigation system evaluations, demonstrate how evaluations are performed, explain how on-farm efficiency can be increased, and provide information on irrigation scheduling programs and techniques. Each mobile lab consists of a van or truck with the necessary tools and equipment to properly evaluate all types of irrigation systems, which are evaluated in the field by crew members. Following an irrigation system evaluation, improvement recommendations are developed and explained to the farmer.

4. Recommend more efficient pre-irrigation techniques.

Suppliers should promote: 1) tailoring pre-irrigations to meet the actual needs for leaching and soil moisture storage; 2) pre-irrigation with an appropriate system which will provide good distribution uniformity⁴ and reduce to a minimum undesired deep percolation.

The purposes of pre-irrigation are to store water in the root zone for later use by the developing crop and for weed control, salt management, seed bed preparation, composting, and wildlife habitat. Soils have specific water holding capacities (depending upon texture) beyond which water is not retained in the root zone. Excess water would become deep percolation. (The Mobile Labs⁵ program could be expanded to help in this important area.)

5. Promote/provide evaluations of on-farm irrigation systems.

Irrigation evaluations such as those provided by Mobile Labs and other consulting services can identify correctable problems such as worn nozzles, uneven spacing, uneven nozzle sizes, excessive run length, etc. Also, evaluations may identify when and where over- or under-irrigation occurs. For those suppliers which utilize an irrigation specialist, on-farm irrigation system evaluations could be part of the supplier's overall program, thus supplementing the efforts of other services or Mobile Labs. (Presently, more than 20 local agencies participate in the Mobile Labs program, which alone since 1981 has evaluated more than 2,000 fields in California -- about 1% of the total number.)

6. Provide irrigation management improvement services.

An on-farm irrigation improvement program conducted throughout the irrigation season identifies problems and the management changes needed to improve field irrigation efficiency. Information collected through the program can be used to assess current water management efficiency and identify corrective measures. (Westlands Water District currently provides intensive irrigation improvement services to its farmers. In this program the District pays a portion of the farmer's cost to hire an approved independent irrigation consultant. The consultant evaluates irrigation system performance and management during the irrigation season and makes recommendations for improvement, including an evaluation of the benefits and cost. The consultant also provides irrigation scheduling services.)

B. Physical and Structural Improvements

1. Provide and use water-measuring devices.

Supplier delivery systems, as well as on-farm systems, are improved by water-measuring devices, such as meters, flumes, weirs, electric pump meters, and engine hour meters. These would allow district managers and the growers to accurately evaluate the benefits of infrastructural improvements and changes made in on-farm water use practices. Records can be included with billing statements, showing the previous year's water use for the same period, for example, and so permit evaluation of the effects of changes in irrigation management, crop selection, and land use practices from year to year.

Planning and evaluation of water management programs depend upon the accuracy of the best available data. Comprehensive and consistent water measurement and data collection should be required of all suppliers as the first step in the implementation of water management policies.

Additional benefits might be greater availability of crop and regional water application data. Flow-measuring devices can assist farmers in getting maximum benefit from water and salinity management practices.

In addition, farmers should be encouraged to voluntarily measure groundwater withdrawals. Well monitoring is critical to evaluation of management programs.

2. Line ditches and canals or use pipelines⁶ when appropriate.

Seepage and evaporation losses in ditches and canals can be minimized by replacement with pipelines or lining with bentonite clay, concrete, or newer pour-in-place plastics/textile membranes. To reduce on-farm seepage losses, suppliers should consider helping farmers line earth ditches or replace ditches with pipelines, except where seepage has been determined to be an effective component of a groundwater recharge program. The costs to implement this EWMP may be beyond the financial ability of a water supplier and may require external financing. Care must be taken to identify potential wildlife impacts and loss or gain of farmable acreage before implementation. (U.S. Department of Agriculture-Soil Conservation Service cost-sharing may be available for some practices.)

⁶In addition to enhancing the accuracy of water measurements, an in-ground pressurized pipeline delivery system allows on-demand delivery to growers, saves ditch maintenance costs, eliminates operational spills, evaporation losses, and losses to phreatophytes. When determined as a cost-effective measure, suppliers should install pressurized pipelines.

C. Institutional Adjustments

3. Evaluate storage, conveyance, and drainage systems.

Present conditions must be thoroughly assessed in order to adequately evaluate the conservation potential for applying any EWM. Suppliers should monitor and evaluate the: 1) flexibility of water delivery, including advance notice required to receive, change, and stop farm deliveries, and the latitude allowed the farmer regarding the time-of-day changes that can be made; 2) accuracy of flow measurement and stability of flow rate delivery to farms at various points within the system (i.e., how much the flow rate and pressure fluctuates during the delivery period at a turnout); 3) awareness by supplier personnel of engineering and management solutions to provide water in a flexible and reliable manner to farmers; 4) destination of applied water; 5) on-farm irrigation methods and practices and awareness level of farmers regarding options for improvement.

4. Recommend the use of on-farm tailwater recovery systems where appropriate.

Tailwater recovery systems are designed to capture irrigation water that runs off the low end of a field, store it, and reapply it to the same field or on a nearby field. Tailwater systems may be useful for three reasons: they 1) can increase irrigation efficiency; 2) can conserve water; and 3) may reduce drainage problems.

1. Allow changes or flexibility in the water contract year.

Many irrigation water suppliers now provide water service on a fixed water-year basis. This arrangement can foster a philosophy of "use it or lose it." It may be possible to allow more flexibility if the contract year is altered to better fit the water-use characteristics of the crops being grown.

2. Change the fee structure in order to provide incentives for efficient use of water.

Suppliers should seek such additional authorities as needed to derive and use funds from a variety of sources, including water rate design, to provide economic incentives to support EWMs.

In some areas of California, the price of irrigation water is relatively low, often purchased at a flat rate. Thus, other aspects of farming receive more attention (such as fertilizer or pest management) than water management. Water prices can play an important factor in overall water management. A few suppliers already are using alternative pricing structures for water, such as tiered pricing, either for irrigation water or drainage disposal. Any excess funds could be used to improve district delivery facilities or be loaned to farmers to improve on-farm irrigation systems or management. Deficits may be more difficult to manage.

Tiered rates, sometimes also known as block rates, can be designed to increase the price of water for increasing quantities of water delivered to the farmer. Because the price of water plays an important role in the management of water, the basic purpose is to discourage the over-application of water.

Tiered rates for surface water sold to growers in agricultural areas may be an efficient and practical means to encourage water conservation. As a result, water supply districts should seriously consider the implementation of these rates as several districts already have. Because of issues such as leaching requirements, groundwater substitution, relative shortness of surface supplies, crop, soil and climatic conditions, suppliers must be free to shape tiered rate designs to specific conditions.

3. Increase flexibility in water delivery to the farmer.

Many factors affect the efficiency of irrigation water use. Among these are soil texture, uniformity, surface gradient, length of irrigation run, weed growth, trash from previous plant growth, the chemistry of the irrigation water, the chemistry of the root zone soil, the depth of the unsaturated zone, wind velocity, humidity, air temperature, design and condition of the water application system, and the degree of expertise of the farmer.

If all of the above factors are optimum, but the water to be applied to the soil is not available to the field at the optimum time or in the optimum amount, the resulting irrigation efficiency will be adversely affected. The uncertainty of weather forecasting does not allow a farmer sufficient lead time in ordering water. Unlike the operation of a municipal water system, an agricultural water supplier's system usually is not able to furnish water on demand, and many times not even within several days of the time at which delivery is requested.

Flexibility of the supply is limited because: a) the supplier may have limited access to the water source; b) the supplier's conveyance system capacity is limited; c) storage within the supply system may be inadequate.

EFFICIENT WATER MANAGEMENT PRACTICES FOR AGRICULTURAL WATER SUPPLIERS

⁷**Arranged-demand water delivery:** the day or days of water availability are arranged between the water supplier and the user; the rate and duration of irrigation water application is controlled by the user.

Some supplier systems are limited in ability to serve the farmer on an arranged-demand⁷ basis because at the time the system was designed the value of arranged-demand response was not as well understood, or the investment capital was not available to construct such a system. Historically, the supply of water generally was greater than the demand, thus the value of water use efficiency was not a large factor. Some suppliers and some farmers have not yet considered the costs and benefits of redesigning and altering their supply systems.

The efficiency of water use is extremely important, but should not be the sole determinant for choosing a distribution system. The efficiency of both capital and labor use are factors which usually dictate a compromise in system choice.

As the relationship between flexible water deliveries and the efficiency of on-farm irrigation practices becomes better understood, there will be increased interest on the parts of farmers and water suppliers to consider operations and delivery system improvements.

It is possible from an engineering standpoint to redesign a supplier's delivery facilities to achieve water savings through flexible delivery. Farmers may not be able to pay for the facilities. However, outside entities may be willing to help fund water-saving facilities.

4. Develop public information programs.

Suppliers could provide farmers with information on the potential for on-farm water conservation. Farmers might find new ways to improve their own systems. Many suppliers have excellent information programs which publicize specific actions farmers have taken and the measured benefits from taking that action. Other farmers then have the opportunity to evaluate those same actions for their own benefit. Programs should be developed that explain why as well as how improving irrigation management is beneficial.

⁸**Conjunctive use:** the operation of a groundwater basin in coordination with a surface water-storage and conveyance system. The purpose is to recharge the basin during years of above-average water supply to provide storage that can be withdrawn during drier years when surface supplies are below normal.

5. Promote conjunctive use⁸ of ground and surface waters.

Continual, long-term groundwater overdraft is a problem that must be addressed. Recharge of conserved agricultural water and storing it in groundwater basins for use during drought emergencies is a sound water management practice.

Conjunctive use programs make use of the storage capacity of groundwater aquifers to allow the redistribution (in time and place) of water from when and where it is available to when and where it is needed. While planned seepage to groundwater

by over-application of irrigation water, canal seepage and so forth may represent important conjunctive use measures in some areas, incidental or unintended losses should not be promoted as conjunctive use. Conjunctive use programs, of necessity, need adequate recharge and extraction capability. Where it is impractical for a supplier to implement a conjunctive use program, suppliers should consider a program with other suppliers. It must be recognized that new conjunctive use programs are expensive. The need for dual surface/groundwater systems requires the additional cost of keeping pumps in standby condition.

6. Facilitate voluntary transfers of water between suppliers.

Many suppliers have internal "pool" arrangements whereby customers who have excess water can sell or transfer the excess to other users within the supplier's service area. Kern County Water Agency has a pool arrangement to transfer water and payments between suppliers within KCWA's service area. Thus, available supplies are maximally used. Lack of flexibility in transferring excess water could lead to a "use it or lose it" philosophy that does not encourage conservation.

Water suppliers should work to remove or mitigate any unnecessary barriers to the voluntary transfer, exchange or marketing of conserved water.

7. Adopt performance goals where appropriate.

Management techniques driven by performance goals and monitored by accurate measurement can lead to more efficient water use. For example, performance goals could include reduced system losses, improved irrigation efficiency, reduced seepage, and improved drainage management.

8. Facilitate voluntary retirement of land (from irrigation) which is not economically feasible to farm.

The water supplier does not have the authority or the responsibility to determine whether land should be retired from irrigation. In the event the land owner makes such a decision, the supplier should facilitate alternative beneficial uses of the water. (Retiring land from irrigation may create problems involving weed and pest control and toxic soils.)

EFFICIENT WATER MANAGEMENT PRACTICES FOR AGRICULTURAL WATER SUPPLIERS

9. Encourage use of reclaimed water that meets all health and safety criteria.

Use of reclaimed water for agricultural irrigation purposes should be in accordance with provisions of Sections 13550, 13551, and 13552 of the California Water Code.

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On-Farm Practices

I. Introduction

Water is the lifeblood of California: for agriculture, for municipalities and industry, and for the environment. We are faced with harsh realities: an uncertain economy; unpredictable water supplies marked by multi-year droughts; a burgeoning population that must be fed, clothed, and housed; and declining fish and wildlife resources, several to the brink of extinction. California's State Water Resources Control Board and also federal legislation now are requiring major actions to restore fish and aquatic conditions, especially in the San Francisco Bay-Delta Estuary and its tributary watersheds. New water projects in California are unlikely until the urban and agricultural sectors exhaust the opportunities for using already-developed supplies to their optimum potential.

Current conditions have created increasing competition for water now dedicated to urban and agricultural uses. Additionally, it is recognized that there is not unlimited water that can be transferred from agriculture to satisfy urban growth in California. There is a commitment that a larger share of California's water is needed to restore and maintain aquatic environmental resources that have been impaired by water development projects.

Advances in plant genetics may yield varieties of crops that require less water per unit of crop production or have a higher salt tolerance than current varieties, with resultant agricultural water savings. In dealing with current realities, it is recognized that advances already made in irrigation science -- the subject of this paper -- are yielding more efficient water use now.

How much water can be generated by agricultural water conservation is a question that has been before water professionals, environmental supporters, and the public for the past decade. This question has two important considerations: how much can be achieved by the actions of water suppliers and how much by improvements in farm irrigation practices?

Questions about agricultural water use and conservation should be addressed against: a projected 11 million increase in the state's population by the year 2010; greater allocations of existing water supplies to fish, wildlife, and other environmental purposes; the effects of water availability on California's food supply; and the effects of water supply on agricultural exports and the likely increase in food imports, with resultant impacts on the state's economy.

Agriculture, in addition to being a stable and major element of California's economy, is both a way of life and a livelihood. These are significant factors in understanding the differences in objectives in domestic use of water vis-a-vis agricultural water

requirements. When making decisions, a farmer must take many factors into consideration (discussed under "Farming Is A Business," pages D-4 to D-6). While economic considerations are primary to farmers, consumer choices dictate what a farmer grows.

II. Background

The Agricultural Conservation Task Force (ACTF) of the State Water Conservation Coalition (a joint project of the Southern California Water Committee and the northern California-based Committee for Water Policy Consensus) has completed a policy statement and list of Efficient Water Management Practices (EWMPs) for agricultural water suppliers. The Coalition believes that on-farm practices may account for a significant portion of the potential for water conservation in California and requested the ACTF to prepare an on-farm practices paper.

III. Purposes/Objectives

The objective of this paper is twofold. One of the primary purposes is to enhance the public's understanding regarding agricultural water use and the various factors involved in irrigation management decisions.

The other primary purpose of this paper is to identify and promote the aggressive implementation of those on-farm practices that will economically improve water use efficiency. While agricultural water suppliers cannot mandate on-farm water use, farmers are urged to support programs for incentives and disincentives that will encourage efficient on-farm use of water (e.g., pricing policies, loan programs, drainage fees, technical and transfer assistance, and so forth). The use of incentives and disincentives can influence more efficient use of water.

Key objectives of efficient, effective on-farm practices are to improve and increase the quantity and quality of crop yield, with associated economic and water conservation benefits. There are likely to be long-term financial benefits to irrigators from implementing efficient on-farm practices.

An additional purpose of this paper is to round out the total picture of water conservation and efficient use opportunities in California; to help ensure that the breadth of water issues is addressed. (The Coalition's scope of work on conservation and efficient use also includes: urban conservation; reclamation and reuse; and

voluntary water transfers and exchanges.) In terms of agricultural water use, the supplier level and the on-farm level both need to be considered. There are differences between what can be done by agricultural water suppliers and what can be done on-farm regarding conservation opportunities.

The Coalition's efforts are concentrated on identifying the range of policies, programs, and practices that will achieve conservation or more efficient use of California's water resources. It is not the purpose of the Coalition nor this paper to recommend what should be done with any water conserved through implementation of efficient on-farm practices.

IV. Guiding Principles

The Coalition urges farmers to adopt the following principles in managing agricultural water supplies, recognizing that there exists a wide variety of conditions and objectives throughout California:

1. **Recognize that appropriate stewardship of agricultural land and water resources contributes positively to maintaining a quality habitat for people as well as for fish and wildlife resources.**
2. **Strive to minimize the amount of irrigation water to produce crop yields consistent with economic conditions and long-term productivity.**
3. **Adopt water management practices that benefit and preserve long-term groundwater resources with respect to quality and quantity.**
4. **Set and meet efficiency targets for various water conservation measures.**
5. **Maintain a long-term view of the use of land and water resources and also give attention to drainage and salinity impacts on productivity of immediate and downslope lands.**

6. Use appropriate irrigation techniques and update irrigation equipment and management as they become economic and as indicated by the best available scientific information.
7. Plant crops and varieties that are consistent with market opportunities, the cost and availability of water, and other factors.
8. Seek resolution to local detrimental effects to others from changes in tailwater flow or water quality.
9. Consider proposals for water transfers that will benefit both buyer and seller, taking into account measures which resolve third-party and other impacts.

V. Farming Is A Business

The public should understand that farming is a business and must generate income to provide a comparable return on investment, labor, management, and risk, as with any viable economic enterprise. As a business, farming involves decisions based on many critical factors:

1. Water supply
 - a. reliability
 - b. cost
 - c. quality
 - d. quantity
 - e. source (surface or well)
2. Regulatory requirements

3. Economics
 - a. market conditions for crops produced
 - b. production costs
 - c. crop prices
4. Soil and topography
5. Climate
 - a. temperature (heat, frost, growing season)
 - b. rainfall (amount and timing)
 - c. wind conditions
6. Labor availability and cost
7. Infrastructure

Hand-move sprinklers in
mature orchard.



Farmers must economically manage all farming inputs, including the cost of irrigation. A few years ago the cost of irrigation was a smaller part of crop production costs. Irrigation costs have dramatically increased in recent years due to rising environmental requirements and to rising energy, water, and labor costs. This has reduced the farmer's profit margin and increased the management required to control irrigation costs as much as possible.

Pressurized systems often are suggested as the way to conserve water, such as changing from flood irrigation to sprinklers. Whether gravity or pressurized, a well-designed and well-managed system appropriate to the field's terrain, soil, crop, and flow constraints can achieve the maximum attainable distribution uniformity over the life of the system. On-farm irrigation evaluations conducted by the California Department of Water Resources and others indicate that the management of the irrigation system is, in fact, more important in improving irrigation efficiency than the type of irrigation system utilized. Furthermore, the cost of more intensive management usually is less than installing and operating alternative systems. Good management maximizes the efficiency of any irrigation system.

Farmers must consider increased energy requirements, as well as associated economic and environmental costs, required to operate a pressurized system. Labor costs and availability and initial capital costs also must be weighed by the farmer before any system is selected.

VI. Promoting On-Farm Irrigation Efficiency in General

Improvements in on-farm irrigation efficiency should consider the effect of such improvements on locally available water supplies and possibly on other factors, including water quality and energy use.

The following guidelines may be useful: Farm irrigation practices that reduce runoff or deep percolation may decrease the quantity of water farmers must order or pump from their wells, but generally will not make water available for alternative uses. Only those practices which reduce evaporation from water or soil surfaces, reduce evapotranspiration, or reduce unrecoverable losses to saline water bodies can provide water for alternative uses.

Studies over many years have sought to quantify potentials for real water savings. Estimated savings depend upon conditions and assumptions made. In brief, little water can be conserved in areas where return flows (surface flows and deep percolation) generally are now being reused, such as in the Central Valley. In those situations where more efficient practices do not lead to real water savings, attention to such practices still may be important to reduce leaching of plant nutrients, lessen degrading groundwater quality, reduce drainage needs, and possibly increase net return per acre.

ON-FARM PRACTICES

¹IE = Irrigation Water
Beneficially Used/(divided by)
Irrigation Water Applied x 100

Efficient irrigation management requires that precise, controlled quantities of water be applied evenly throughout the field. Attainable distribution uniformity (DU) sets the upper limit of irrigation efficiency (IE), unless the field is under-irrigated. As its name implies, DU is the measure of how evenly the water infiltrates into the soil profile across the field. IE measures how efficiently water is applied to meet beneficial uses.¹ Beneficially used water (BU) is the amount of irrigation water that satisfies a portion or all of the following: evapotranspiration, leaching requirement, special cultural practices, and/or stored in the soil for use by crops.

The leaching requirement is the amount of water required to flush a sufficient quantity of accumulated salts from the root zone downward to maintain full crop productivity. All irrigation water naturally contains salt. Many soils in irrigated areas contain natural salts and additional salts result from weathering. High concentrations will reduce crop yield. As crops utilize the water, salts are left behind in the soil. These salts must be leached out to maintain germination and crop productivity.

IE can be used to determine how efficiently irrigation(s) are performed on a single field, a farm, or on a large area such as an irrigation district. Seasonal Application Efficiency (SAE) is a term used by some agencies to estimate area-wide irrigation efficiency.²

²SAE = (Evapotranspiration -
Effective Precipitation +
Leaching Requirement Depth
+ Water for Cultural Practices)
/(divided by) Applied Water

The average DU of irrigation systems evaluated by the California Department of Water Resources, Resource Conservation Districts, Westlands Water District, and other entities is now about 70-75 percent. System design and management were found to have greater impacts on DU than the type of system. Analysis of the evaluations of some irrigation systems shows that the DUs of well-managed production-scale fields irrigated by furrow, sprinkler, or trickle systems rarely exceed 80 percent during the system's life even though some DUs are higher on small-research plots. An average DU of 80 percent is only attainable for a system that is properly designed when the field terrain, soil texture and slope, and crop are considered. A system with an average annual field DU of 80 percent can be expected to achieve a maximum IE of 75 percent when irrigations are properly timed, the soil is well-drained, and portions of the field are under-irrigated. Under-irrigation in any part of the field results in increased soil salinity and reduced crop yields. Therefore, additional water must be applied to the entire field. This would reduce the attainable irrigation efficiency to 73 percent. These efficiency goals may be unrealistic under some farming conditions.

The destination of the applied water (AW) is shown on the following diagram (page D-9). This diagram graphically shows water movement through the soil when all of it is applied at a DU of 80 percent. This diagram shows where 36 inches of AW goes when it is used to grow a crop. Minor evaporative losses account for 6 percent (2-1/4 inches) of AW. About 26 inches satisfies evapotranspiration (ETAW) and 7-3/4 inches goes to leaching and deep percolation (DP). The 7-3/4 inches of DP is not

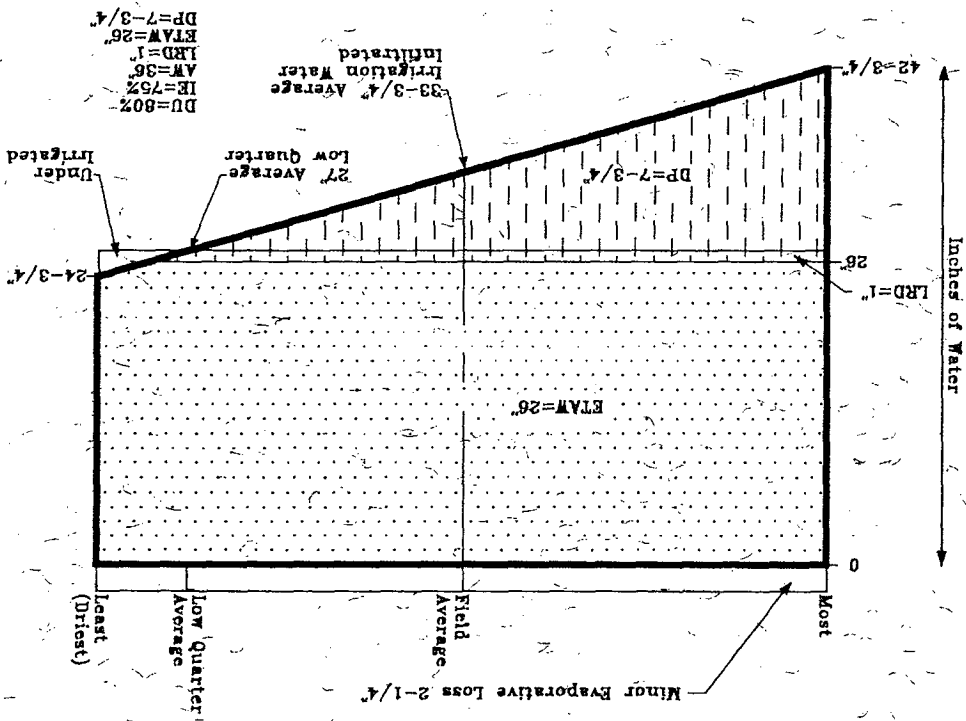
ON-FARM PRACTICES

uniform across the field. It varies from 0 to 16-3/4 inches. The leaching requirement depth (LRD) is one inch, the minimum amount of water required to maintain salt balance in the soil profile. The remaining 6-3/4 inches of deep percolation may be used later by a deeper rooted crop or percolate into a useable aquifer. Deep percolation is only lost if its final destination is a salt sink or saline shallow groundwater.



Furrow irrigation of cotton.
Water (in this photo) is
delivered to furrows with gated
surface pipe.

Sample Water Destination Diagram for Any Irrigation System



DU (Distribution Uniformity) = The ratio of the average low-quarter depth of irrigation water infiltrated to the average depth of irrigation water infiltrated, expressed as a percent.

$$DU = (27'' / 33.75'') \times 100 = 80\%$$

$$IE \text{ (Irrigation Efficiency)} = (BU / AW) \times 100 = (27'' / 36'') \times 100 = 75\%$$

AW = Applied Water

LTD = Leaching Requirement Depth

ETAW = Evapotranspiration of Applied Water

DP = Deep Percolation

Technical guidance and assistance is available to irrigators from a variety of sources. Farmers are urged to avail themselves of the many opportunities to benefit from such assistance. For example, irrigators are encouraged to obtain information from such entities as:

1. **University of California Cooperative Extension agricultural programs**
2. **U.S. Department of Agriculture**
 - U.S. Soil Conservation Service
 - U.S. Agricultural Research Services
 - U.S. Agricultural Stabilization & Conservation Service
3. **U.S. Department of the Interior**
 - U.S. Bureau of Reclamation
4. **Local Resource Conservation District**
5. **California Department of Water Resources (e.g., CIMIS, Mobile Labs program, Ag Water)**
6. **Agricultural research information available from various colleges, universities and public and private sector publications**
7. **Irrigation design and management consultants (public and private sector)**
8. **Agricultural water suppliers**

On-farm irrigation efficiency is affected by a variety of factors, including:

1. **Management**

The goal of any commercial farming operation is to maximize farm profits by managing the operation's inputs and risks. The importance of good farm management cannot be overemphasized. Water resources management is only one aspect of the operation's overall management needs. Other management needs include: land use, crop growth, fertility, financing, labor, equipment, pests, disease, weather, government regulations, processing, storage, transportation, marketing, and accounting. Management priorities must be weighed against one another as measured by their impacts on profits. Also, management priorities must be adaptable to changing conditions.

2. Soil Type and Topography

Soil characteristics and topography affect crop selection, irrigation method, and irrigation scheduling, as outlined in the following paragraphs. Coarse or fine-textured soils and sloping lands often present problems which determine crop mix and irrigation practices.

3. Crop Selection

Crop selection, from a cultural perspective, should consider: local climatic conditions; availability and quality of water; soil type, depth, and infiltration rate. Some examples of poor choices would be orchards on poorly-drained soil, almonds where frosts occur into March, beans on flat, tight soil, cotton where summer nights are cold, or rice on sandy soil. There are, however, times when farmers, for economic reasons, plant crops for which the area or soils are not optimal. Growers attempt higher net return crops even though they may not be best-suited to their farm. Farmers are not always in a position to simply choose the crop best adapted to the area.

4. Suitable Irrigation Method

The method of irrigation and system design should be suited to the water supply, crop, land configuration, and soil. The least costly form of irrigation is often furrow and border strip due to their relatively low energy requirements and hardware costs.



Matching the irrigation system to terrain is very important, as illustrated by this drip-irrigated orange grove.

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These methods can achieve high efficiencies, particularly on medium to fine textured uniform soils, especially when tailwater is re-used. Low efficiencies can occur when these methods are used on very high intake rate soils and fields with significant variations in soil textures in the direction of irrigation. Both cross slopes (side-fall) and irrigation runs (end-fall) should be appropriate and uniform. Land grading can reduce both slopes and remove undulations but deep cuts and fills or shallow soils can make this practice very costly or impractical and adversely affect soil productivity.

Sprinkler and micro (drip, minisprinkler, perforated tubing) irrigation methods with potential for high irrigation efficiencies are suited to many crops and terrain. However, sprinkler efficiencies can be low in windy and high evaporation areas. The practicability of sprinkler and micro can be limited due to relatively high system costs, energy requirements, and/or labor requirements. Sprinklers are not recommended where poor quality irrigation water can damage crop foliage. Drip irrigation is not now proven practical on full ground cover crops such as pasture, grains, and alfalfa.

5. Irrigation Scheduling

Irrigation scheduling involves the decisions of when to irrigate and how much water to apply. Decisions based on tradition and experience may be improved by a more scientific approach, which can lead to greater irrigation efficiency and the potential to increase crop yields. Scientific irrigation scheduling generally involves estimating an allowable soil moisture depletion and predicting the rate of crop evapotranspiration (ET) to forecast when the next irrigation should occur. Factors taken into consideration include: crop type and stage of growth, method of irrigation and application system characteristics, potential ET based on climatic

Laser leveling can greatly improve distribution uniformity of an irrigation system.



factors, and soil water-holding capacity. Improved irrigation scheduling practices may identify fields that currently are over-irrigated but also may identify the need to apply more water to fields that are under-irrigated.

Ideally, the water delivery system allows the farmer to receive water on the day required by the crop and at a rate and duration that will replenish the soil moisture depletion while minimizing losses. Under these conditions, when water is available on demand, scientific scheduling can be implemented, with the potential to significantly improve on-farm irrigation efficiency and crop yield. However, unlike urban water supplies, irrigation water is rarely available immediately on demand. Instead, most farmers have to order water one or more days in advance of the scheduled date, making it difficult to respond to changing weather and field conditions. Furthermore, water may not be available exactly when ordered or it must be taken at a fixed rate or for a fixed period of time. These constraints reduce the potential of irrigation scheduling to improve irrigation efficiency. The most constraining situation is when water is delivered "in rotation" so that the farmer has no control over the irrigation date and usually only limited control over the rate and duration of delivery. In this case, the potential benefits of scheduling -- improved crop yield and reduced water use -- may be very limited. The potential of irrigation scheduling to improve efficiency varies widely throughout California, due to the widely variable conditions under which irrigation water is available to farmers.

6. Irrigation Cost

Superficially, the unit total cost of agricultural water appears to be much lower than for urban water. However, a valid comparison can only be made after considering a number of factors. The cost of agricultural water delivered to the farmer represents only a fraction of the irrigation cost. At the source, urban water costs are comparable with the costs of agricultural water, but increases in total cost on the way to the faucet. Urban water must meet evermore-stringent drinking water standards and may be delivered from relatively new facilities such as the State Water Project, conveyed hundreds of miles through open canals, lifted over mountain ranges, treated, tested, pumped through complex distribution systems, and billed by the three-hundredth of an acre-foot. Urban water customers also enjoy greater supply reliability than farmers; state law gives priority to domestic use of water over irrigation use.

Agricultural water, on the other hand, is untreated and is often delivered from older, local systems that have long since been paid for. Farmers must invest hundreds of dollars per acre for land preparation and/or pressurized delivery systems and booster pumps, as well as pay for energy, water management, irrigation labor, and reuse or drainage.

The following table provides examples of costs to apply one acre-foot of water to one acre with: a gated pipe furrow system with a one-eighth mile run and tailwater reuse; a hand-move sprinkler system; and a drip/trickle system on a 160-acre cotton field in the Western San Joaquin Valley. It takes about 3.0 acre-feet of water per acre to obtain maximum crop yields. These costs are typical for properly designed systems. In addition to cost, system selection should be based on field terrain, soil texture, water supply, and energy availability and cost.

Irrigation Costs per Acre-Foot of Applied Water

	Furrow	Sprinkler	Drip
Capital ³	\$30	\$19	\$ 68
O&M ⁴	19	33	11
Energy	2	26	9
Water	25	25	25
Management ⁵	4	4	4
TOTAL	\$80	\$107	\$117

³Capital Cost: Cost of replacing, expanding, and/or improving irrigation equipment. The annual capital cost is determined by amortizing the acquisition cost over the life of the equipment. Examples of capital items: gated pipe, conveyance pipe, sprinkler pipe, heads and nozzles, booster pumps, drip lines, and filtration equipment.

⁴Operation and Maintenance Costs: Costs of labor, equipment, and material to operate and maintain an irrigation system. Examples: Installing and removing gated pipes or ditches, moving sprinkler pipe, setting and adjusting flow rates, and repairing irrigation systems.

⁵Management Cost: Cost to determine when to irrigate and how much to apply.

Source: Westlands Water District Irrigation Cost Evaluator

Many farmers also pay taxes or assessments to the agricultural water supplier above and beyond water rates, which further increases the cost of irrigation. These taxes and assessments may be used to pay for water distribution, drainage collector and management systems, and other capital, operations and maintenance costs, and legal defense of water rights and contracts.

7. Reliability of Supply

The irrigator who has a reliable supply of water at a reasonable cost can be expected to continuously improve his efficiencies. The farmer with an unreliable water supply is less able to invest in improvements that would increase irrigation efficiencies.

8. Considerations for Irrigators Pumping from Groundwater

Many farmers depend in part or entirely on groundwater for irrigation. In areas with frequent inadequate surface water supplies necessary for agricultural water needs, the conjunctive use of surface and ground water supplies is vital to farm success. When surface supplies are plentiful, groundwater pumping decreases, providing an opportunity for the groundwater basin to recharge. Groundwater pumping increases during times of drought.

Costs are associated with groundwater use in addition to the ever-increasing energy costs required to pump the water. Equipping and installing a groundwater well can cost a farmer in excess of \$250,000 in parts of California. Even so, there is no guarantee that the well will initially and continuously provide the desired flow and/or water quality. Costs are also incurred for operation, maintenance, and repair.

Farmers who depend on groundwater are often limited in the types of crops they can grow. If the wells produce poorer quality water than surface supplies, farmers may only be able to grow crops which are moderately to highly salt tolerant. Also, extra water may need to be applied to leach the soils to maintain a salt balance.

Farmers who rely on well water risk pump and well failures. If a pump or well fails during periods of high crop water demand, a whole crop may be lost. And as water levels decline during a drought, energy costs also greatly increase.

VII. List of Specific On-Farm Practices

Growers are encouraged to aggressively implement appropriate, reasonable, and economically-justifiable on-farm water management practices. These are listed below to provide a summary of practices that are currently in use in California, some of which are in the forefront of technology. For the general public, this list serves to illustrate the complexity of irrigation as a science. For the farmer, this may serve as a checklist and to encourage investigation of possible improvements to current practices.

A. Effective General Water Management Practices

Regardless of the method of irrigation used (e.g., furrow, border strip, level-basin/border, hand-move sprinklers, solid set sprinklers, and micro irrigation), certain guidelines should be considered routinely as applicable to any method of irrigation.

1. Occasionally conduct irrigation system evaluations, such as those provided by Mobile Labs or similar services, to provide feedback on distribution uniformity (DU) and irrigation scheduling decisions.
2. Seek the assistance of farm advisors, irrigation consultants, Soil Conservation Service, or other resources to help identify water management improvement opportunities and to assist in the adoption of economically advantageous practices.

3. Know your soil. Keep a map available with the soil description, including important physical characteristics of soils such as texture, soil depth, water-holding capacity, soil salinity, and intake rate.
4. Monitor soil profile salinity throughout the field to assure that a root-zone salt balance is being maintained.
5. Hire, train, and retain irrigators skilled in effectively managing water and the irrigation equipment involved.

B. Practices Specific to Common Irrigation Methods

Listed below are practices for each of the most common irrigation methods used in California. It is important to note that several of these practices may not be effective or necessary in some areas.

1. FURROW (Sloping)

a. Practices to Optimize Uniformity of Water Application

- 1) Increase the rate of water advance to the end of the field by:
 - a) Using high initial onflow rates to each furrow.
 - b) Using relatively short furrow lengths.
 - c) Laser grading for a uniform slope (remove high and low spots).
 - d) Laser grading for a steeper slope.
 - e) Using "torpedoes" or other methods to smooth furrow surfaces after cultivations.
- 2) Respond to soil texture (water intake rate) variations in the field by:
 - a) Using surge irrigation.
 - b) Consider changing to sprinkler or micro irrigation methods.

b. Practices to Efficiently Control Tailwater

- 1) Reduce onflow rates after water has advanced to the end of the field.
- 2) Capture runoff in a properly planned and designed tailwater recovery system.
- 3) Re-use captured runoff in an efficient manner.
- 4) Take advantage of tailwater reduction features available with surge irrigation.

c. Practices to Respond to High Intake Rate Soils

- 1) Use surge irrigation.
- 2) Switch to portable sprinklers during high intake rate periods.
- 3) Irrigate less frequently (considering crop water stress tolerance).
- 4) Irrigate alternate furrows.

Furrow irrigation used in
grape vineyard.



d. Practices to Optimize Water Application Timing and Amount Decisions

- 1) Develop a water budget irrigation scheduling strategy which considers each of the following:
 - a) Allowable or desirable crop water stress.
 - b) Available water-holding capacity within effective rooting depth of crop.
 - c) Water availability and/or delivery constraints.
 - d) Very small water applications (1" - 2") result in poorer uniformities.
 - e) The ability of rainfall to meet part of the seasonal crop water requirement (effective rainfall).
 - f) Timing of farm cultural practices such as cultivations, fertilizer applications, harvest, etc.
- 2) To help decide when to irrigate, track crop water needs directly by monitoring soil profile moisture (e.g., by sample and feel method or with moisture-sensing devices) and/or plant stress techniques (e.g., with leaf water potential or infrared devices). In addition, climate-based crop water use techniques such as CIMIS should be utilized to account for soil variability and to simplify monitoring.
- 3) Use a soil moisture (deep wetting front) probe as a tool to help decide when to shut off the water.
- 4) Install and utilize water flow meter/measuring devices or methods to monitor the flow rate so that the volume applied to each irrigation set can be calculated.

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⁶"Sub the beds": practice of running irrigation water in furrows until the tops of the beds are darkened with water (via water moving by capillary action from furrow into and up the beds between the furrows).

- 5) Record irrigation dates and amounts applied to each field. Then, regularly compare soil-based and/or CIMIS-type crop water use data with actual water application records to serve as a check on irrigation scheduling decisions.
- 6) Advocate and support flexible (frequency, rate, and duration) water deliveries from suppliers.
- 7) If irrigation set times required to "sub the beds"⁶ result in excessive deep percolation from the bottom of the furrows, consider:
 - a) Probing the beds to check for actual adequacy of wetting (it is usually not necessary to completely "blacken" the tops of the beds).
 - b) Re-configuring future beds (making them lower and/or narrower) to reduce subbing time.
 - c) Change irrigation methods to sprinkler or micro to better provide near-surface moisture.

2. BORDER STRIP (Sloping)

- a. Practices to Optimize Uniformity of Water Application
 - 1) Encourage equal water "standing time" throughout each border strip length by matching the water advance rates (water covering the surface) with recession rates (water leaving the surface) by:
 - a) Establishing (tracking) the water recession rate.
 - b) Producing the desired advance rate by:
 - Increasing or decreasing the onflow rate to each strip
 - Adjusting border spacings
 - Laser grading for a uniform slope
 - Laser grading for a minimum cross slope and desired irrigation slope.
 - 2) Respond to significant soil texture variations (water intake rate) within each strip by changing to sprinkler irrigation.
- b. Practices to Efficiently Control Tailwater
 - 1) Shut the water off before it has advanced to the end of the field.
 - 2) Capture runoff in a properly planned and designed tailwater recovery system.
 - 3) Re-use captured runoff in an efficient manner.
- c. Practices to Optimize Water Application Timing and Amount Decisions
 - 1) Develop a water budget irrigation scheduling strategy which considers each of the following:

- a) The amount of water which the strip will "take" (infiltrate) uniformly.
 - b) Available water-holding capacity within effective rooting depth of crop.
 - c) Allowable or desirable crop water stress.
 - d) Water availability and/or delivery constraints.
 - e) The ability of rainfall to meet part of the seasonal crop water requirement (effective rainfall).
 - f) Timing of farm cultural practices such as cultivations, fertilizer applications, harvest, etc.
- 2) To help decide when to irrigate, track crop water needs directly by monitoring soil profile moisture (e.g., by sample and feel method or with moisture-sensing devices) and/or plant stress techniques (e.g., with leaf water potential or infrared devices). In addition, climate-based crop water use techniques such as CIMIS should be utilized to account for soil variability and to simplify monitoring.
 - 3) Use a soil moisture (deep wetting front) probe as a tool to check the adequacy of irrigation.
 - 4) Install and utilize water flow meter/measuring devices or methods to monitor the flow rate so that the volume applied to each irrigation set can be calculated.
 - 5) Record irrigation dates and amounts applied to each field. Then, regularly compare soil-based and/or CIMIS-type crop water use data with actual water application records to serve as a check on irrigation scheduling decisions.
 - 6) Advocate and support flexible (frequency, rate, and duration) water deliveries from suppliers.

3. LEVEL-BASIN/BORDER IRRIGATION (dead level)

a. Practices to Optimize Uniformity of Water Application

- 1) Basin design should consider:
 - a) Level basins should not be used on high-intake rate soils.
 - b) There should be little water-intake rate variation (uniform soils).
 - c) Water onflow or delivery rate should be adequate to cover the basin quickly enough to assure uniform application.
 - d) Basin must be precision leveled.

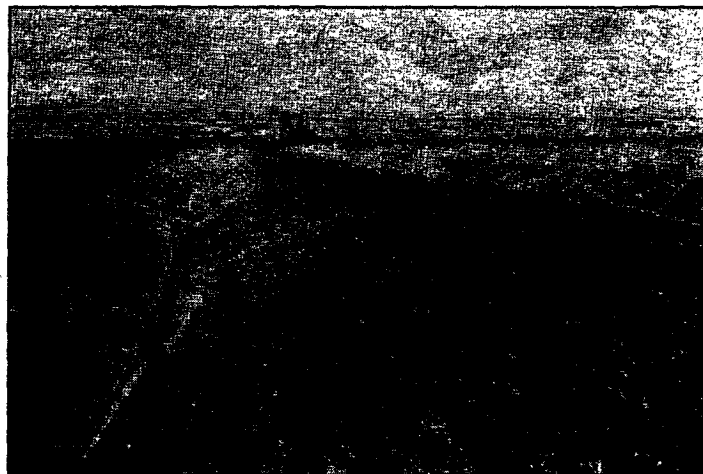
- b. Practices to Optimize Water Application Timing and Amount Decisions
- 1) Develop a water budget irrigation scheduling strategy which considers each of the following:
 - a) Allowable or desirable crop water stress.
 - b) Available water-holding capacity within effective rooting depth of crop.
 - c) Water availability and/or delivery constraints.
 - d) The ability of rainfall to meet part of the seasonal crop water requirement (effective rainfall).
 - e) Timing of farm cultural practices such as cultivations, fertilizer applications, harvest etc.
 - 2) To help decide when to irrigate, track crop water needs directly by monitoring soil profile moisture (e.g., by sample and feel method or with moisture-sensing devices) and/or plant stress techniques (e.g., with leaf water potential or infrared devices). In addition, climate-based crop water use techniques such as CIMIS should be utilized to account for soil variability and to simplify monitoring.
 - 3) Use a soil moisture (deep wetting front) probe as a tool to check the adequacy of irrigation.
 - 4) Install and utilize water flow meter/measuring devices or methods to monitor the flow rate so that the volume applied to each irrigation set can be calculated.
 - 5) Record irrigation dates and amounts applied to each field. Then, regularly compare soil-based and/or CIMIS-type crop water use data with actual water application records to serve as a check on irrigation scheduling decisions.
 - 6) Advocate and support flexible (frequency, rate, and duration) water deliveries from suppliers.

4. HAND-MOVE SPRINKLERS

- a. Practices to Optimize Uniform Water Application
- 1) Have new systems designed by a competent irrigation designer. A good design will provide:
 - a) Adequate mainline and lateral sizes, and appropriate system layout considering topography, to minimize pressure variations.
 - b) Proper sprinkler head spacing and lateral move distances to provide adequate overlap.

ON-FARM PRACTICES

- c) An application rate less than the intake rate of the soil.
 - d) Adequate use of pressure regulators.
 - e) The use of pressure controls or nozzle size selection to achieve uniform application on hilly terrain.
 - f) Consideration for windy conditions.
 - g) A well-chosen filtration/sand separation system.
 - h) Proper operating pressure.
 - i) Proper riser heights to avoid spray interference by crops.
- 2) Set up and operate the system as designed in regard to:
- a) Operating pressure
 - b) Lateral move distances
 - c) Lateral sizes and lengths
 - d) Number of laterals operated each set
 - e) Proper placement of laterals
- 3) Perform regular inspection and maintenance, addressing:
- a) Filter operation
 - b) Gasket leakage
 - c) Nozzle wear and plugging (do not mix nozzle sizes during replacement)
 - d) Sprinkler head operation
 - e) Pipe damage



Hand-move sprinklers in operation.

- 4) Use alternate sets (offset laterals one half of a move distance every other irrigation).
- 5) Avoid irrigating during windy periods when practical.

b. Practices to Minimize Evaporation Losses

- 1) Avoid irrigating during windy periods when practical.
- 2) Maintain sprinkler head pressures below the "misting point".
- 3) Avoid water applications of one inch or less.

c. Practices to Optimize Water Application Timing and Amount Decisions

- 1) Develop a water budget irrigation scheduling strategy which considers each of the following:
 - a) Allowable or desirable crop water stress.
 - b) Available water-holding capacity within effective rooting depth of crop.
 - c) Water availability and/or delivery constraints.
 - d) The ability of rainfall to meet part of the seasonal crop water requirement (effective rainfall).
 - e) Timing of farm cultural practices such as cultivations, fertilizer applications, harvest, etc.
- 2) To help decide when to irrigate, track crop water needs directly by monitoring soil profile moisture (e.g., by sample and feel method or with moisture-sensing devices) and/or plant stress techniques (e.g., with leaf water potential or infrared devices). In addition, climate-based crop water use techniques such as CIMIS should be utilized to account for soil variability and to simplify monitoring.
- 3) Use a soil moisture (deep wetting front) probe as a tool to check the adequacy of irrigation.
- 4) Install and utilize water flow meter/measuring devices or methods to gauge the volume of water applied to each irrigation set.
- 5) Record irrigation dates and amounts applied to each field. Then, regularly compare soil-based and/or CIMIS-type crop water use data with actual water application records to serve as a check on irrigation scheduling decisions.
- 6) Advocate and support flexible (frequency, rate, and duration) water deliveries from suppliers.

5. SOLID-SET SPRINKLERS

a. Practices to Optimize Uniform Water Application

- 1) Have new systems designed by a competent irrigation designer. A good design will provide:

ON-FARM PRACTICES

- a) Adequate mainline and lateral sizes, and appropriate system layout considering topography, to minimize pressure variations.
 - b) Proper sprinkler head and lateral spacings to provide adequate overlap.
 - c) An application rate less than the intake rate of the soil.
 - d) Adequate use of pressure regulators.
 - e) The use of pressure controls or nozzle size selection to achieve uniform application on hilly terrain.
 - f) Consideration for windy conditions.
 - g) A well-chosen filtration/sand separation system.
 - h) Proper operating pressure.
 - i) Proper riser heights to avoid spray interference by crops.
- 2) Operate the system according to the design parameters.
 - a) Operate at the design pressure.
 - b) Operate laterals as designed.
 - 3) Perform regular inspection and maintenance, addressing:
 - a) Filter operation
 - b) Nozzle wear and plugging (do not mix nozzle sizes during replacement)
 - c) Sprinkler head operation
 - d) System damage
 - 4) Avoid irrigating during windy periods when practical.
- b. Practices to Minimize Evaporation Losses
- 1) Avoid irrigating during windy periods when practical.
 - 2) Maintain sprinkler head pressures below the "misting point".
 - 3) Avoid water applications of one inch or less.
- c. Practices to Optimize Water Application Timing and Amount Decisions
- 1) Develop a water budget irrigation scheduling strategy which considers each of the following:
 - a) Allowable or desirable crop water stress.
 - b) Available water-holding capacity within effective rooting depth of crop.
 - c) Water availability and/or delivery constraints.
 - d) The ability of rainfall to meet part of the seasonal crop water requirement (effective rainfall).
 - e) Timing of farm cultural practices such as cultivations, fertilizer applications, harvest, etc.
 - 2) To help decide when to irrigate, track crop water needs directly by monitoring soil profile moisture (e.g., by sample and feel method or with

moisture-sensing devices) and/or plant stress techniques (e.g., with leaf water potential or infrared devices). In addition, climate-based crop water use techniques such as CIMIS should be utilized to account for soil variability and to simplify monitoring.

- 3) Use a soil moisture (deep wetting front) probe as a tool to check the adequacy of irrigation.
- 4) Install and utilize water flow meter/measuring devices or methods to gauge the volume of water applied to each irrigation set.
- 5) Record irrigation dates and amounts applied to each field. Then, regularly compare soil-based and/or CIMIS-type crop water use data with actual water application records to serve as a check on irrigation scheduling decisions.
- 6) Advocate and support flexible (frequency, rate, and duration) water deliveries from suppliers.

Drip irrigation in young almond orchard.



6. MICRO IRRIGATION (micro sprinkler, micro-jet, or surface or sub-surface drip)

a. Practices to Optimize Uniform Water Application

- i) Have new systems designed by a competent irrigation designer. A good design will provide:
 - a) Adequate submain pipeline and tubing sizes, and appropriate system layout considering topography, to minimize pressure variations.
 - b) Application rates which do not cause surface runoff.
 - c) Adequate use of pressure regulators at manifold and lateral inlets to minimize pressure variations.

- d) The use of pressure-compensating emitters on hilly terrain.
 - e) A well-chosen filtration/sand separation system as recommended by the emitter/tubing/spray head manufacturer.
 - f) Automatic filter backflush.
 - g) Proper operating pressure.
 - h) An automatic chemigation system to inject fertilizer, and chlorine, acid and other agents to prevent emitter/tubing plugging.
 - i) Adequate wetted area.
- 2) Operate the system at the design pressure.
- 3) Perform regular inspection and maintenance such as:
- a) Filter operation inspection.
 - b) Check for emitter/tubing/spray head plugging (do not mix spray heads or emitters of varying rated discharge rates during replacement).
 - c) Regularly flush submains, manifolds, and tubing.
 - d) Inspect spray head operation.
 - e) Inspect for damage caused by animals, cultural practices, or other factors.
 - f) Monitor operating pressure on submains and manifolds.
- b. Practices to Optimize Water Application Timing and Amount Decisions
- 1) Develop a water budget irrigation scheduling strategy which considers each of the following:
- a) Allowable or desirable crop water stress.
 - b) Available water-holding capacity within effective rooting depth of crop.
 - c) Water availability and/or delivery constraints.
 - d) The ability of rainfall to meet part of the seasonal crop water requirement (effective rainfall).
 - e) The discharge rate of the emitter/spray head/tubing:
- 2) To help decide when to irrigate, track crop water needs directly by monitoring soil profile moisture (e.g., by sample and feel method or with moisture-sensing devices) and/or plant stress techniques (e.g., with leaf water potential or infrared devices). In addition, climate-based crop water use techniques such as CIMIS should be utilized to account for soil variability and to simplify monitoring.
- 3) Use a soil moisture (deep wetting front) probe as a tool to check the adequacy of irrigation.
- 4) Install and utilize water flow meter/measuring devices or methods to gauge the volume of water applied to each irrigation.

- 5) Record irrigation dates and amounts applied to each field. Then, regularly compare soil-based and/or CIMIS-type crop water use data with actual water application records to serve as a check on irrigation scheduling decisions.
- 6) Advocate and support flexible (frequency, rate, and duration) water deliveries from suppliers.